US Army Corps
of Engineers

1987 Annual Report

The Hydrologic Engineering Center

Research   Technical Assistance   Training

4

This annual report describes the accomplishments of the Hydrologic Engineering Center (HEC) during FY 1987 and presents the planned program for FY 1988.
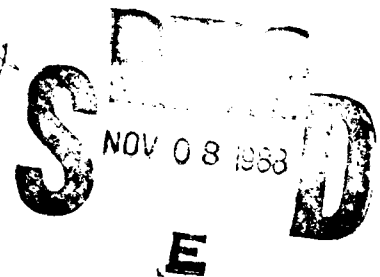
TABLE OF CONTENTS

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DIRECTOR'S MESSAGE

The Center provided substantial technical assistance to 23 Corps offices during FY 1987. Technical assistance was also provided to the Federal Highway Administration and the Federal Emergency Management Agency. More than one-third of HEC's resources were devoted to direct field assistance projects during FY 1987. Five or more offices were assisted in each of the areas of Real-Time Water Control and Data Management, River Hydraulics, Rainfall/Runoff and Reservoir Systems.

Fifteen formal training courses involving 11 weeks of training were conducted at HEC. Six workshops, totaling 18 days, were also held.

Important advances were made in improving HEC's library of computer programs during FY 1987. Fifteen new programs were developed; most serving the water control data management area. Many existing HEC programs, including HEC-2, were upgraded to Fortran 77 standards to make them more transportable to other computer systems. Twenty-four HEC programs were added to the 28 personal computer versions (MS DOS compatible) available in FY 1986. The 52 PC versions cover most HEC technical areas, including rainfall-runoff, river hydraulics, floodflow frequency, flood damage computations, groundwater analysis, small-scale hydropower costs, and spatial data management.

Significant enhancements were made in improving our ability to do work in a PC workstation environment. The MENU2 program developed for HEC-2 was expanded to provide similar capabilities for HEC-1, HEC-5, and HEC-6. A general purpose editor (COED) was enhanced for use in the workstation environment. COED now contains a full screen data editing capability, and HELP command capabilities for input data records and variables. HELP files for the COED program were developed for HEC-1, HEC-2 and HEC-5. An interactive input preparation program for HEC-1 was initiated.

Activity within the Corps and HEC remain high with regard to acquisition and use of microcomputers. Some Corps Hydraulics/Hydrology offices (including HEC) already have IBM PC/AT or Compac 386 (or equivalent) microcomputers on each engineers' desk. HEC is planning on having 15 microcomputers dedicated to classroom use for FY 1989. In our third full year of distributing microcomputer versions of our programs, requests were four times that for the mainframe versions and PC requests increased 84% over last year.

Meaningful new capabilities were provided to our Corps users in several areas. New water control software packages were developed to enhance the Corps' ability to manage real time data needed in forecasting and operating reservoir systems. Important new capabilities were also added to our real-time reservoir regulation analysis.

An interactive program (MOD5) to provide capabilities to easily change operational criteria during simulation of flood control reservoir systems was developed. This program will insulate infrequent program users of simulation models from the normal program input requirements and allow them to easily change operational criteria during flood emergencies.

The increased role of the PC in HEC's work was highlighted by the conversion of our largest program (HEC-5) to the PC, and the acquisition of 14 new microcomputers (which use the 80386 chip). These new PCs, for a single user, rival our Harris 1000 minicomputer in execution speeds.

The distribution of workload at HEC during 1987 changed considerably from FY 1986, as can be seen by Table 1. The training program experienced a slight drop in FY 1987, and the research program decreased by 22%. Technical assistance efforts were increased accordingly to compensate for the other decreases. The overall manpower and funding levels were essentially unchanged for FY 1987, and no significant change is anticipated for FY 1988.

The planned program for FY 1988 includes activities similar to FY 1987. Our increased Training and Research program, however, will have to be offset by decreasing our technical assistance activities.

An important milestone in our PC program development, expected in FY 1988, will be the implementation of our Data Storage System (HEC-DSS) on the PC. DSS provides convenient data transfer among our computer programs. The use of menu driven programs to develop or modify input files to HEC-1, HEC-2, and HEC-5 remains a high priority. The programs will compliment the generalized capability available in COED to edit or create input files in full screen mode. Two new R&D work units are scheduled to start in FY 1988 in the areas of "River Analysis" and "Catchment analysis". A new research program entitled "Cost-Shared Hydrologic Analysis" will be performed by HEC. It consists of three work units: "Project Performance," "Community Flood Threat," and "Hydrologic/Hydraulic Analysis Design."

Emphasis will continue on advancing the technical capabilities of our programs, modernizing the computer program code, and creating a more friendly computational environment for our users. We will be concentrating on providing these capabilities for microcomputers, as well as mainframe.

Table 1
HEC Activities Based on Funds Expected
(in percent)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988*
Training	9	15	10	9	14
Computer Support	12	17	16	16	16
Research	39	45	40	31	36
Technical Assistance	40	23	34	44	34
Total	100	100	100	100	100

*Estimated

GOALS OF THE HYDROLOGIC ENGINEERING CENTER

The goal of the Hydrologic Engineering Center (HEC), designed to help achieve the goals of the Chief of Engineers, is to support the nation in its water resources management responsibilities by increasing the Corps technical capability in hydrologic engineering and water resources planning and management. An additional goal is to provide leadership in improving the state-of-the-art in hydrologic engineering and water resources planning.

By means of programs in research, training, planning analysis, and technical assistance, every effort is made to be aware of the problems and needs of the Corps and the nation, to keep abreast of the latest developments throughout the profession, and to make use of this information in a manner best suited to the needs of the Corps.

HEC increases the effectiveness of the Corps and the profession by bridging the gap between the academic community and practicing hydrologic engineers and planning professionals. Research or training activities that can be best accomplished by universities are not undertaken. HEC incorporates state-of-the-art procedures and techniques into manuals and comprehensive computer programs. The procedures are made available to the Corps, the national, and international professionals through an effective technology transfer system of technical assistance, publications, video tapes, and training courses.

Research supplements relevant research at universities, private industry and other agencies. It develops systematic procedures that produce a quality product and also save time for experienced specialists and enable less-experienced personnel to use procedures effectively.

Training efforts develop the U.S. Army Corps of Engineers work force and reduce the time necessary for young engineers and planning professionals to become proficient in hydrologic analysis, and, in addition, familiarize more-experienced professionals with new developments.

Technical assistance provides advice and assistance to Corps field personnel in the application of new or unfamiliar procedures to solve unusual water resources problems and to more effectively utilize USACE resources.

Planning analysis developes and enhances analytical techniques and procedures to be applied in the water resources planning activities in Corps field offices to enable the production of a quality product.
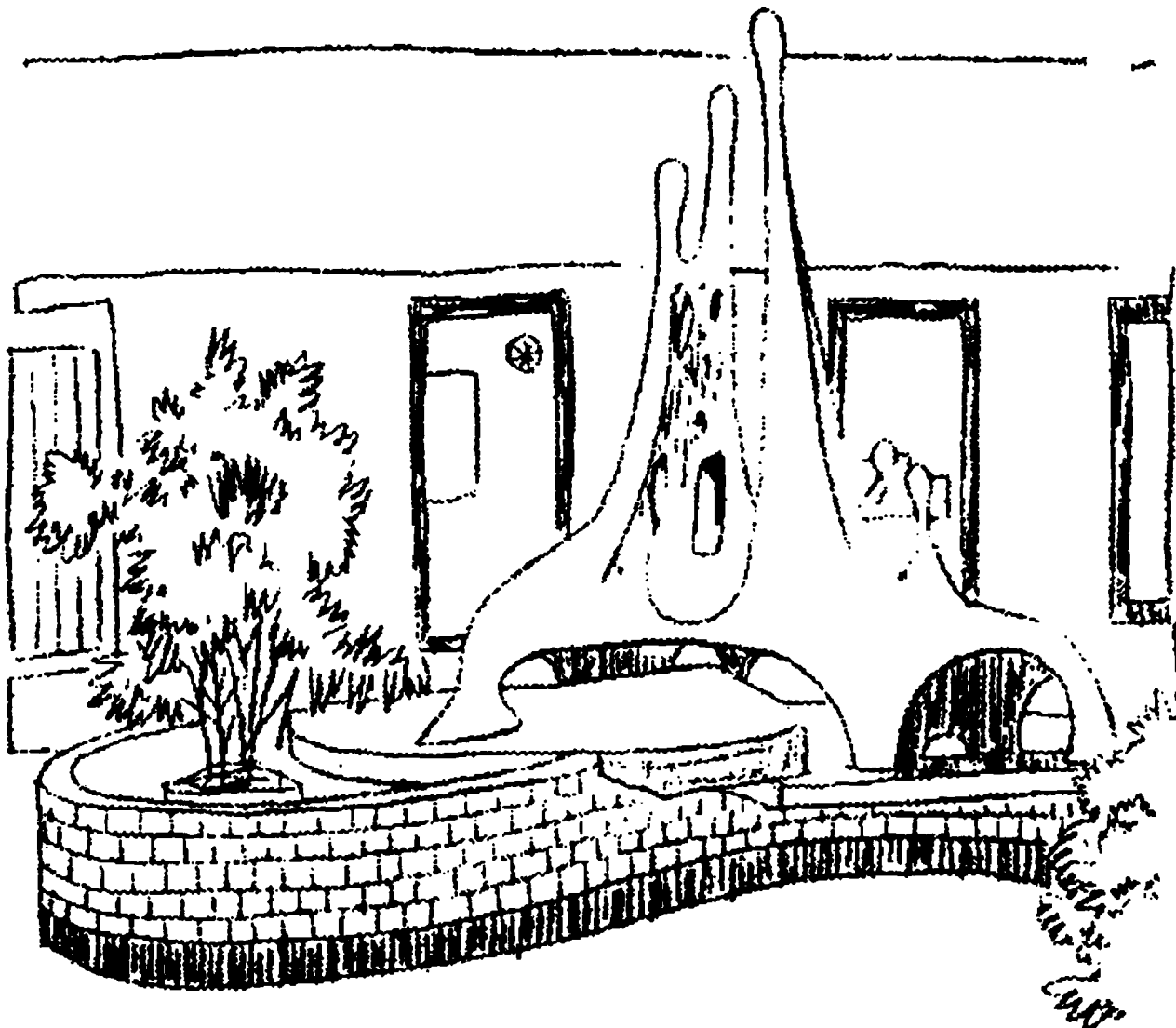
ADMINISTRATION/FUNDS

The Hydrologic Engineering Center is located in Davis, California. Facilities include office space for the staff and visiting personnel, a well-equipped classroom for 36 students, a library, a publications and video tapes storage center, and a computer facility. The computer hardware consists of a HARRIS 1000 computer, and a variety of supporting video, graphics and printing terminals. Fourty-two personal computers and twelve graphic terminals (for classroom use).

Personnel, finance and accounting, contract, supply, and reproduction services are supplied to HEC (under support agreements) by the Sacramento District.

Responsibilities

The HEC was established in 1964 to provide applied research, training, and technical assistance in hydrologic engineering to Corps field offices. In 1971, HEC's responsibilities were expanded to include analytical planning so that activities of the HEC now address a wide range of hydrologic engineering and analytical planning concerns.

The annual program of HEC is based on: (1) program direction from the Office of the Chief of Engineers, Civil Works Directorate (Planning Division), and the Engineering and Construction Directorate (Hydraulics and Hydro-

logic Division); (2) the Corps Research and Development Directorate's activities; (3) requests for assistance by Corps field offices; (4) cooperative work with other Corps research laboratories; and (5) cooperative work with other government and professional organizations. This program is reviewed at an annual conference held with personnel from the Office of Chief of Engineers, the Corps R&D Directorate, the Water Resources Support Center, and interested Corps field offices.

The HEC is part of the Water Resources Support Center located in Fort Belvoir, Virginia. The Water Resources Support Center coordinates Corps-wide water resources support services for the Directorate of Civil Works, Office of the Chief of Engineers. The HEC has been granted authority, within the approved program, to deal directly with field offices on technical matters.

Organization and Staff

The HEC is organized into five functional units as shown on the accompanying organization chart. HEC was authorized 36 full-time equivalent positions during FY 1987 and for FY 1988. Those persons employed on permanent status at the end of FY 1987 are shown on the organization chart. The HEC also employs temporary employees in professional, technician, and clerical capacities. Six students were also employed at HEC during FY 1987. An Intergovernmental Personnel Appointment position was occupied by a Utah State University faculty member who provided special hydrologic engineering technical expertise to the HEC.

Funding

HEC funding is provided by three main sources: the Civil Works R&D program, a Corps-sponsored training program, and reimbursable services provided to Corps offices and other agencies. Resimbursable assistance includes work for Corps District and Division offices; research and development laboratories; the Water Resources Support Center; the Planning Division, Civil Works Directorate, Office of the Chief Engineers; Hydraulics and Hydrology Division of the Engineering and Construction Directorate; Office of the Chief of Engineers; and other government agencies. Income and expenditure summaries for FY 1987 and projection for FY 1988 are shown in the following table.
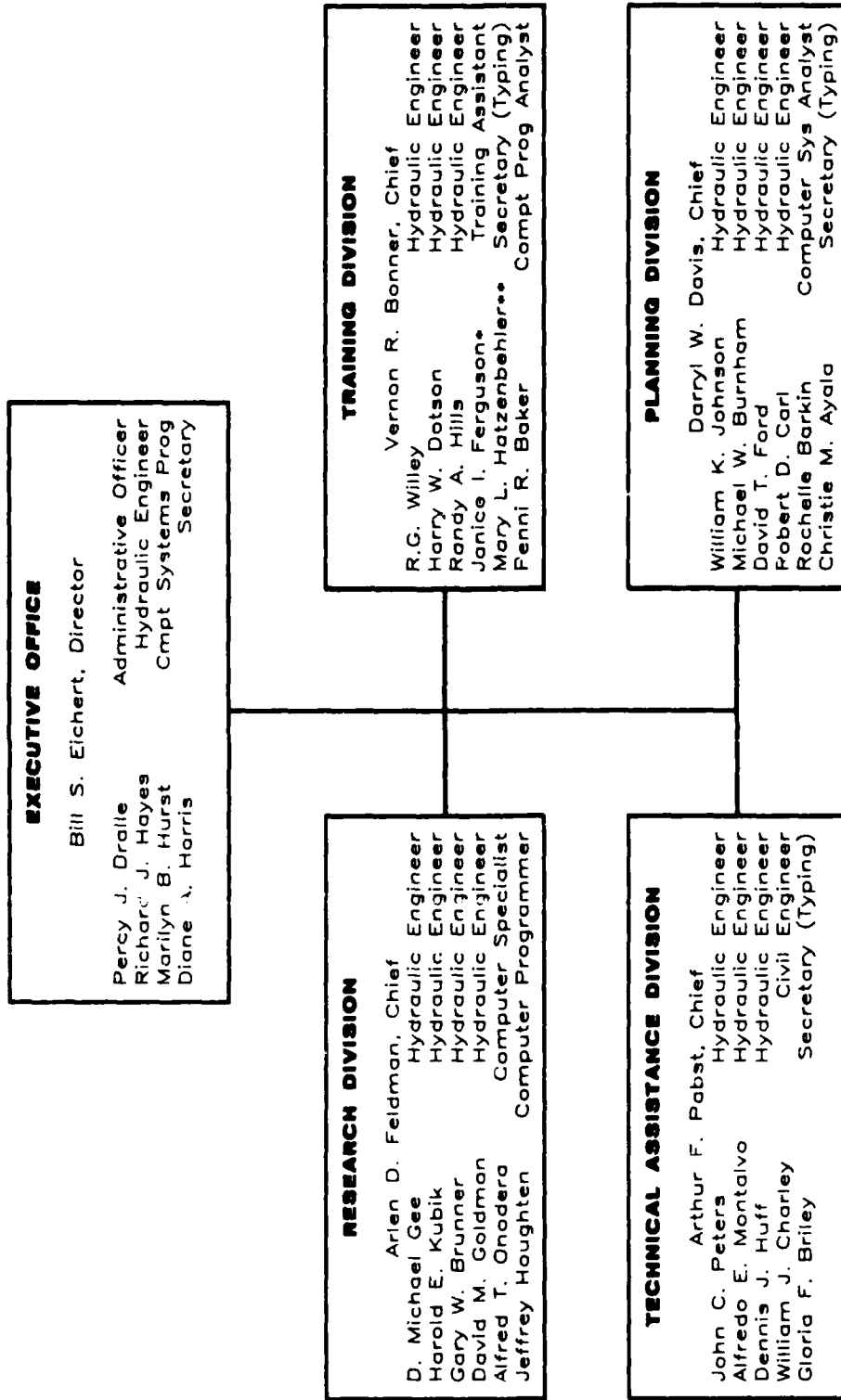
Income and Expenses Summary, FY 1987
($1,000)

	FY 1987	Estimated FY 1988
Income		
R&D, Direct	$?05	$ 1,014
R&D, Reimbursable	239	120
Training	285	442
Technical Assistance	948	698
Floodplain Management	45	70
Computer Program Support (GE funds)	185	185
Publications and Computer Program Income	254	250
Multi-year money from Previous FY	414 [1]	342
	$ 3,075	$ 3,121
Expenses		
Salaries and Benefits	$ 1,528	$ 1,560
Travel and Per Diem	84	80
Research Contracts	202	200
Professional Services	14	15
Computer Time and Equipment	186	185
ADP Maintenance	69	70
Reproduction	47	50
Services and Supplies	135	124
Space Rental	127	151
Administrative Services[2]	341	375
Subtotal	$ 2,733	$ 2,810
Multi-year Money not expended	342	311
Total	$ 3,075	$ 3,121

[1]Includes $9,000 R&D carryover
[2]Provided by Sacramento District

3

THE HYDROLOGIC ENGINEERING CENTER

EXECUTIVE OFFICE

Bill S. Eichert, Director

Percy J. Dralle	Administrative Officer
Richard J. Hayes	Hydraulic Engineer
Marilyn B. Hurst	Cmpt Systems Prog
Diane A. Harris	Secretary

TRAINING DIVISION

Vernon R. Bonner, Chief

R.G. Willey	Hydraulic Engineer
Harry W. Dotson	Hydraulic Engineer
Randy A. Hills	Hydraulic Engineer
Janice I. Ferguson*	Training Assistant
Mary L. Hatzenbehler**	Secretary (Typing)
Penni R. Baker	Compt Prog Analyst

PLANNING DIVISION

Darryl W. Davis, Chief

William K. Johnson	Hydraulic Engineer
Michael W. Burnham	Hydraulic Engineer
David T. Ford	Hydraulic Engineer
Robert D. Carl	Hydraulic Engineer
Rochelle Barkin	Computer Sys Analyst
Christie M. Ayala	Secretary (Typing)

RESEARCH DIVISION

Arlen D. Feldman, Chief

D. Michael Gee	Hydraulic Engineer
Harold E. Kubik	Hydraulic Engineer
Gary W. Brunner	Hydraulic Engineer
David M. Goldman	Hydraulic Engineer
Alfred T. Onodera	Computer Specialist
Jeffrey Houghten	Computer Programmer

TECHNICAL ASSISTANCE DIVISION

Arthur F. Pabst, Chief

John C. Peters	Hydraulic Engineer
Alfredo E. Montalvo	Hydraulic Engineer
Dennis J. Huff	Hydraulic Engineer
William J. Charley	Civil Engineer
Gloria F. Briley	Secretary (Typing)

Summary — Positions Used

31 Full—Time Permanent
1 Part—Time Permanent
_____
32 Total

Only permanent personnel are shown

* Part—Time employee
**Employee is on a one—year leave of absence

4

RESEARCH

Corps field office needs are the foundation of HEC's research program. New research needs are also identified by Corps headquarter offices, as well as other Federal agencies. Most of HEC's research effort is technique-oriented and emphasizes a generalized solution to specific field problems. Research results are transferred to the field through HEC's training and technical assistance programs as well as through Corps manuals, regulations, and HEC computer programs.

Planning, design, construction, operation and maintenance of today's multiple-purpose water projects require complex interdisciplinary analyses. These complex problems present major methodological and computational tasks to the water resources planner and engineer. The HEC seeks solutions to these problems through development of systematic methods and the use of modern digital computers.

Research Program Accomplishments, FY 1987

Research activities were carried out in 16 work units. These work units represent specific technical areas that have been identified in the Corps R&D program. The HEC's primary research area is entitled "Analytical Techniques in Water Resources Planning Studies." The HEC was also involved during FY 1987 in the Corps research programs for water conservation and supply, planning

methodologies, remote sensing, and dam safety. The FY 1987 work units are listed below.

Research Work Units, FY 1987

Improvements in Methods of Evaluating Hydrologic Phenomena

Computer Methods for Water Resources Planning

Real-Time Reservoir Regulation

Modernization of Computer Programs

Water Resource Data Storage System

Flood Forecasting Models for Use During Flood Emergencies

Analytical Techniques for Evaluating Reservoir Systems

Water Quality Procedures for Water Control Management

Flood Warning Systems

Hydrologic Techniques for Leveed Interior Areas

Spatial Data Management and Analysis System

Hydrologic Methods for Determining Water Supply Potential

Groundwater Analysis, Recharge and Storage

Remote Sensing and Spatial Data Applications

Hydrologic/Hydraulic Risk Assessment of Dams

Risk Concepts in Flood Hydrology and Damage Analysis

The **Improvements in Methods of Evaluating Hydrological Phenomena** work unit addresses basic studies in hydrology, statistical methods and river mechanics. Work items include simulation of rainfall/snowmelt/runoff processes, flow frequency analysis, stochastic hydrology, water surface profiles, unsteady flow flood routing and sediment transport. An analysis of HEC's future watershed model capability was made and general requirements specified. Artificial intelligence techniques were investigated for use in HEC computer programs. A methodology for development of volume-duration-frequency pattern hydrographs is being developed. The Flood Flow Frequency EM is being prepared for publication. A new EM on flood routing was proposed and the general content outlined.

The **Computer Methods in Water Resources Planning** work unit emphasizes the development of procedures and tools for automated flood damage analysis, nonstructural flood damage reduction studies, risk and uncertainty in planning, and other general aspects of water supply planning. The initial microcomputer (PC) based flood damage analysis package that includes basic flood damage programs, menu shell, preliminary data management system, and interim documentation was completed. The first phase PC workstation based spatial data management and analysis system was also completed. EAD and SID program enhancements were finished and user documentation for BANK and SID was revised and reissued.

The **Real-Time Reservoir Regulation** work unit emphasizes the development of reservoir regulation simulation programs and management information display for water control activities. Updated documentation for HEC-5 and a cut-down version of HEC-5 (to be used for flood control systems during real time operation) were completed. An interactive program (MOD5) to provide capabilities to easily change operational criteria during simulation of flood control reservoir system was developed. This program will insulate infrequent program users of simulation models from the normal program input requirements and allow them to easily change operational criteria during flood emergencies. A new, abbreviated flow format was developed for HEC-5 that allows user-specified releases to be more conveniently and accurately input to the model.

The **Modernization of Computer Programs** work unit seeks to reduce software maintenance costs, improve reliability of production runs, and facilitate future improvements in HEC's hydrologic engineering and analytical planning computer programs. Conversion of HEC programs to FORTRAN 77 (to enhance the portability of the programs and to make them usable on the PC) continued at a high rate. Workstation environment design was completed and menu operations were developed for HEC-1, HEC-2, and HEC-5. A general purpose editor (COED) was enhanced for use in the workstation environment. COED contains a full screen data editing capability, and HELP command capabilities for input data records and variables. HELP files for COED program were developed for HEC-1, HEC-2 and HEC-5. An interactive input preparation program for HEC-1 was initiated.

The **Water Resources Data Storage System** work unit has developed a data storage and retrieval system that allows hydrologic engineering/planning simulation models to communicate with one another. Such a data system eliminates redundant capabilities (such as graphics and statistics) in the individual programs, and makes the software more modular and easier to support. The capability to set a flag on each piece of time series data was

designed. This is required to allow individual data points to be recognized as missing, estimated, forecast, modified, or any other of a variety of user set conditions. This capability will be provided in DSS library, DSPLAY, DSSUTL, REPGEN, and other related products. The system of DSS products is currently being implemented on MS-DOS compatible PC's; the DSS library and DSPLAY are now operational on the PC.

The **Flood Forecasting Models for Use During Flood Emergencies** work unit is directed toward developing a package of programs to use in forecasting the hydrologic response of a river basin. The forecasting techniques developed under this work unit were applied to additional basins for operational use by HEC and district office personnel. Initial design of a simple continuous moisture accounting model is being developed. This model will allow improved estimates of basin infiltration losses, particularly through a series of wet and dry periods. Simplicity will be maintained to facilitate application to areas with little or no historical calibration data.

The **Analytical Techniques for Evaluating Reservoir Systems** work unit develops improved techniques for formulating and evaluating multipurpose and multireservoir systems. This unit addresses the planning, design and regulation aspects of reservoir systems. Regulation aspects refer to the scheduling of releases from proposed projects, not real-time regulation of existing systems. A preliminary shell was developed for the reservoir system programs facilitating program executions and file management on micro-computers (PC). A personal computer version of HEC-5 will the full capabilities of the program was developed. Time-series Data checks were added to the CKHEC5 program. Research needs in the reservoir system area were formulated based on results from a questionnaire to users of HEC reservoir systems program. Improved output capabilities of HEC-5 were added as suggested by user questionnaire. Development and testing of procedures for system-power rule-curve operation were accomplished.

The **Water Quality Procedures for Water Control Management** work unit seeks to develop, document and support computer models capable of evaluating downstream water quality impacts of releases from multipurpose, multi-reservoir systems. A draft of the EC on "Water Quality Modeling of Reservoir Systems for Water Control" has been completed. The EC provides field staff with a manual on how-to-use the HEC-5Q computer program for routine application, to evaluate proposed retrofit projects, or for analysis of real-time reservoir regulation impacts on downstream water quality conditions. Assistance to NPD on applying this model to the Columbia River hydropower operation is continuing. Also, assistance to the Committee on Water Quality was provided for the development of the "Water Quality

'88" seminar, held 23-25 February 1988 in Charleston, South Carolina.

The **Flood Warning Systems** work unit will define needed hardware and develop software packages for use by the Corps in its flood warning projects. These systems will be designed for interlinkage with Corps real-time water control flood forecast/warning systems. HEC hosted an invited seminar on local flood warning/response systems and published a proceeding. A research work plan for near term (18 months) was formulated and work initiated on developing technical document describing the Corps mission, warning/response systems, planning/evaluations methods, and design and implementation needs. Preparations for presentation of training course early next FY were carried out.

The **Hydrologic Techniques for Leveed Interior Areas** work unit seeks to develop hydrologic analysis procedures for planning flood control measures for leveed interior areas. This work unit will develop procedures for efficient analysis of interior flooding by the basic methods of period-of-record, coincident probability, and stochastic analysis. HEC performed a detailed requirements analysis for needed computer programs in hydrologic analysis of interior areas; documented results in a detailed program design report, and initiated development of the computer program. Studies were initiated on analysis of interior and exterior time series data to characterize degree of dependence and coincidence.

The **Spatial Data Management and Analysis (SAM)** work unit supports development of a geographic information system for use in the Corps engineering and planning activities. Geographic information, characterized in grid cells or irregular polygons, can be used to formulate parameters for hydrologic models, flood damage information, or benefit analysis, as well as habitat or land characteristics for use in environmental planning. Durable, lightweight, portable, digitizing hardware (and complementary software) for compatible use with a microcomputer has been acquired. The intent is to create a PC-based workstation for performing digitizing and other GIS analysis. A PC-based GIS has also been procured. User documentation for the Structure Inventory for Damage Analysis program (SID) has been revised, and is available for distribution.

The **Hydrologic Methods for Determining Water Supply Potential** work unit is designed to improve existing analytical techniques to determine water supply potential. Work concentrated on simplifying the use of HEC-5 for performing water supply reservoir simulation studies. A new PC version of the INFIVE Program (interactive input preparation program for HEC-5) was released; it includes color coded MENU's and user responses. A new user manual for INFIVE was also published. The HEC-5 optimization routines were modified to allow use of non-

monthly flow data. The main use of this new capability will be for weekly data, but some use of daily flow optimization is also anticipated.

The **Groundwater Analysis, Recharge and Storage** work unit is designed to document concepts and analytical techniques useful in performing groundwater investigations programs. A package of simulation programs contains a preprocessor, postprocessor (containing Kriging interpolation routines and graphic displays), and the U.S. Geological Survey's groundwater simulation model. A field test project has been completed with the Memphis District that will document application of desktop analysis methods for a surface water groundwater exchange program. The training document is in final draft form. Several field offices have been provided one-stop technical service.

The **Remote Sensing and Spatial Data Application** work unit seeks to investigate how remotely sensed data can be incorporated into a spatial data management system for hydrologic and environmental analyses. A procedural manual for classifying Landsat and other satellite sensor imagery and loading that classified imagery into a grid cell data bank was drafted. The document will be finalized later this FY. The HEC land use classifier was field tested (using the HEC Harris 1000 computer) on the Albuquerque urban area. The testing included resampling the classified image to a larger grid format and interfacing different areas within the same Landsat scene and with an adjoining Landsat scene. A contract was let with Earth Satellite Corp. to investigate current satellite sensor capabilities for real-time flood forecasting and recent advances in digital image processing.

The **Hydrologic/Hydraulic Risk Assessment of Dams** work unit was begun to analyze the benefits from improved spillway capacities to prevent dam failure as compared to the cost of larger spillways. The rare-flood theory report was completed but is being revised to include references to the results of recent interagency and National Research Council studies. The HEC participated in the NRC study on behalf of the Corps. The "Case Studies in Dam Safety Analysis" report was completed and is undergoing Corps review. It presents a risk and uncertainty, and sensitivity, analysis of spillway sizing at two Corps dams.

The **Risk Concepts in Flood Hydrology & Flood Damage Analysis** explores the concept of risk as it relates to flood hydrology and flood damage analysis. Its goal is to develop analysis procedures and study documentation and reporting strategies to better communicate in practical, lay-understandable style, the relationship between risk and flood control project formulation and evaluation. A lay tutorial describing basic risk concepts as related to performance of flood control projects was completed.

Numerical experiments of variability, of flood damage and project benefits as a function of project life, hydrologic variability and project design level were also completed and documented. Flood control project measures performance characteristics were outlined.

Outlook for FY 1988

Research funding is expected to be increased next fiscal year. The current plans are to proceed with most of the existing work units and add five new work units. The Corps is officially discontinuing the Water Supply and Conservation R&D program. That action terminates the "Hydrologic Methods for Determining Water Supply Potential" and "Groundwater Analysis, Recharge and Storage" work units. The general work unit "Improvements in Methods of Evaluating Hydrologic Phenomena" was completed and two new, more specific, work units for river analysis and catchment analysis will begin. A new research program entitled "Cost-Shared Hydrologic Analysis" will be performed by HEC. It consists of three work units: "Project Performance," "Community Flood Threat," and "Hydrologic/Hydraulic Analysis Design." The new work units were approved in the R&D program reviews last fiscal year, but funding may not be adequate to support them. The plans for the existing and new work units are discussed in the following paragraphs.

Computer Methods in Planning will continue to support the growing family of PC-based planning software. It will also include the geographic information system work previously carried out under the "Spatial Data Management and Analysis (SAM)" work unit. The second phase PC-based flood damage analysis package (which includes flood damage programs, hydrologic engineering programs, complete data management package, graphics and report presentation) will be completed. HEC will also maintain modest activity in the water supply area. The Spatial Data Systems activities will complete the second phase of the PC workstation-based capability to perform full range of spatial analysis. An interactive PC analysis, based on RIA program concepts will be implemented. Enhancements to spatial programs (DAMCAL, HYDPAR, RIA, and BANK) will also be made. The decision process related to commercial PC packages/licensing for performing spatial analysis will be formulated.

Real-Time Reservoir Regulation work will integrate the previously developed stand-alone MOD5 program with the HEC water control software.

The **Modernization of Computer Programs** activities will develop/document a set of subroutines to allow FORTRAN programs to perform screen and data management functions on PC's. The interactive input data

preparation program for HEC-1 will be completed. Interfaces with data bases for HEC program input data will also be developed.

Data Storage System activities will finalize DSS user documentation for distribution to field offices. Versions of DSS software will be distributed for Corps Harris systems, MS-DOS PC systems, and generic Fortran 77 systems. An ETL on DSS will be prepared.

Flood Forecasting work will emphasize development of a simple continuous moisture accounting model. This will be implemented initially for use on Harris systems. Final implementation will include PC systems. Model testing using historical and real-time data will be initiated.

The **Reservoir Systems Evaluation** work will seek to reduce the computation time for both mainframe and PC versions of HEC-5. A user friendly PC shell for the HEC family of programs dealing with reservoir systems will be completed. The shell will enhance program executions, input preparation, file management and output display.

The **Water Quality Procedures** activities will complete the Columbia river Basin hydropower operation analysis using HEC-5Q on a short-interval basis. Necessary changes to the study procedure EC and the Users Manual will be documented. The model will be updated as necessary, based on the application results. Coordination of the planning of the Corps Committee on Water Quality Seminar in Charleston, S.C., during February 1988, is also managed under this work unit.

Flood Warning work will complete a technical document on planning, design, implementation of local flood warning - response systems. A preliminary assessment of needed development work in warning systems software/hardware will also be made.

Remote Sensing activities will include development of soil moisture accounting algorithms for the HEC-1 and HEC-1F (flood forecasting version) programs. A simplified approach to soil moisture accounting will be taken (i.e. less complex than the NWS Sacramento Model); the methodology will emphasize use of readily available watershed and hydrometeorologic characteristics. Parameter estimation from gaged watershed data as well as ease of application are prime considerations in developing the soil moisture simulation capability. The use of satellite sensors (e.g. AVHRR) for spatial distribution of precipitation will also be investigated.

Risk Concepts in Flood Hydrology and Flood Damage Analysis activities will prepare additional tutorial material communicating in lay terms, uncertainty in flood damage estimates and project benefit analysis. An investigation into interplay of uncertainty in components of flood damage analysis (e.g. rating curves, flow-frequency curves, and damage potential functions) will be started. A white paper on implications of uncertainty in flood damage estimates in respect to Corps project formulation/evaluation criteria will be outlined.

Hydrologic Techniques for Leveed Interior Areas will complete a preliminary test version of hydrologic analysis of interior areas computer program. Testing will be performed and a test version released to a selected district. The coincidence/dependence technical memorandum will be finalized for dissemination by OCE to the field.

The following paragraphs describe the objectives and plans of the **five new work units** to begin in FY 1988.

The objective of the **Hydrologic Performance of Flood Damage Mitigation Projects** work unit is to develop technical and lay tutorial material that characterizes the hydrologic performance of flood damage mitigation projects. It will investigate needed scope/content and prepare a lay persons tutorial document describing how flood damage mitigation measures function and their respective advantages and disadvantages.

The **Community Flood Threat: Definition of and Communication to Local Governments** work unit will develop technical descriptive material that assists in communicating in an accurate technical, but lay context, the nature of flooding and the reality of the flood threat. An internal memorandum report on community perception of flood threat and information needs and format for high priority flood threat communication products will be prepared. An initial flood threat communication product will be released.

The **Hydrologic/Hydraulic Analysis Design** work unit seeks to define the relationship between technical issue. and alternative analysis methods and scope of hydraulic and hydrologic studies for flood control investigations. It will develop hierarchial narrative material describing these relationships to provide guidance to field offices in formulating and supporting hydrologic engineering studies in cost sharing negotiations. It will also investigate and prepare the skeleton structure for the narrative rationale, prioritize the technical/functional areas to be addressed, and prepare a test example.

The **River Analysis System** work unit will produce a uniform set of tools, based upon existing models, for use by hydraulic and hydrologic engineers in a workstation environment. The tools will focus on the analysis of river hydraulics/mechanics to enhance and accelerate project design and the prediction of project impacts. Specific improvements in HEC-2, to reflect needs of hydraulic design elements of the Corps, will be installed and the code will be modularized. Input will be solicited from field offices

regarding the function and operation of the proposed river analysis system. The general design of the system, including data pathways and specific computational components, will be developed.

The **Catchment Analysis System** work unit will develop methodologies and computer programs for simulation of complex river basin hydrologic processes. An integrated set of computer programs and methodologies for engineering work stations (computer, graphics devices, digitizers, high resolution CRTs, etc.) will be the central focus of the catchment analysis system. This system will be built of modular components with state-of-the-art catchment model as the central component. Techniques will be utilized to assist the user in proper application of the models. The initial work will concentrate on developing a comprehensive design for the catchment analysis system. The design will include data formulation, data handling, hydrologic, and hydraulic techniques, expert systems for data preparation, editing, computation control, results analysis, and results handling for reports and graphics. The emphasis is on both improved hydrologic methods and user effectiveness. User effectiveness not only includes data and results management, but also internal controls to insure proper use of the program.

PLANNING

The goal of the Planning Division is to develop and implement analytical techniques for use by the Corps in water resources management investigations. Areas of emphasis include: development of systematic methods for the formulation and evaluation of alternatives, development of computer programs capable of integrating objectives, performance, cost, benefits, and other important planning factors; development of strategies for using the variety of analytical methods in planning studies; and the integration of computerized information processing with planning. Significant efforts are devoted to consolidating research results into field-usable products that include computer programs, applications documentation, and information dissemination. Work efforts in FY 1987 were in several areas:

Flood-Damage Mitigation Planning
Damage Computations and Data Management
Spatial Data Management
Water Supply Planning
Miscellaneous/Other

Focus continues on the development of practical computer programs and companion user materials for use by field office professional staff. Areas that received particular emphasis this past year include flood damage-mitigation planning, damage computations and data management, and water supply.

11

Flood-Damage Mitigation Planning

Activities in this technical area are concerned with the strategies and technology for formulating flood-damage mitigation plans, developing and managing planning data, and developing and providing information on significant policy issues.

Work has been steadily progressing on developing an analytical strategy for formulating solutions to flood damage mitigation problems through application of the systems analysis technique referred to as 'branch and bound enumeration'. The attractiveness of the technique is that it makes use of existing detailed simulation models and thus does not require the usual simplifying assumptions of other systems analysis methods. The technique has been implemented experimentally for the integrated use of the reservoir systems analysis program (HEC-5) and expected annual damage program (EAD). Further testing is planned to be followed by a more complete general purpose implementation for these and other HEC programs.

Flood warning/emergency preparedness is an important emerging flood damage mitigation measure to be considered as either an integral component of a comprehensive flood control plan or as an interim measure until more complete measures are to be implemented. A seminar was formulated and hosted by HEC that examined the nature of these systems and debated the potential role for the Corps in planning, design, and implementation. A seminar proceedings has been published. As a follow-up to the seminar, a one-week training course was presented that provided instruction to Corps professionals in study of the measures. Additional training and guidelines development is considered to be of high priority and will be undertaken in FY 1988.

The planning process of the Corps is now a two-phased effort consisting of a "reconnaissance" phase conducted by the Corps at 100% federal expense followed by the feasibility phase, when appropriate. The feasibility study is 50% - 50% cost shared with the local sponsor. Many questions have arisen regarding study management, scheduling, level of technical detail, and coordination for the reconnaissance phase. HEC formulated and hosted a 3-day workshop devoted to this subject. Invited participants from OCE, Corps district and division offices, and the HEC made presentations and debated the issues. An increased understanding of the special needs of reconnaissance studies emerged and was documented in a Memorandum For Record now available upon request. Tentative plans are being formulated for another workshop to be held in mid-FY 1988.

The concepts of risk and uncertainty are not well understood by the public and by many professionals in the Corps. Work by HEC in this area has consisted of developing tutorial materials for internal and public distribution, and investigation of the variability in flood risk and associated flood damage and project benefits. A document that is being published as a brochure handout has been completed. Also a brief report documenting the variability in flood damage and benefit estimates has been prepared and is available upon request. The next phase of the work will interpret the variability information developed to date and propose, in a white paper, approaches the Corps might consider in incorporating such information within the planning and decision process.

The HEC FY 1986 Annual Report documented completion and publication of EM 1110-2-1413, Hydrologic Analysis of Interior Areas. A need for a computer program to assist in the hydrologic analysis of these areas became apparent during the preparation of the manual. An interior area analysis computer program that will meet this need was designed this fiscal year. Design will be completed and coding initiated during FY 1988.

Damage Computations and Data Management

The HEC has been working for a number of years toward packaging into an integrated whole, programs needed for flood damage computations and associated data management. The initial goal has been achieved for mainframe and minicomputer systems with the completion of the computer code and procedural methods embodied in the HEC Flood Damage Analysis Package. The package is presented in many HEC training courses and now a one-week PROSPECT course is devoted to its application in Corps studies.

The package is available on Corps Harris computers and is available for installation on MS-DOS compatible microcomputers. The package is comprised of the computer programs HEC-1 (Flood Hydrograph Package), HEC-2 (Water Surface Profiles), HEC-5 (Reservoir Systems Analysis), SID (Structure Inventory for Damage Analysis), SIDEDT (Editor for SID program), DAMCAL (Damage Reach Stage Damage Calculation), EAD (Expected Annual Flood Damage Computation), PIP (Paired Function Input Program for Flood Damage Data), and the HEC-DSS (Hydrologic Engineering Center Data Storage System). The programs are automatically linked through the HEC-DSS thus enabling highly efficient processing of data from original field inventories through integration of hydrologic and hydraulic data in to the damage computation process.

The microcomputer implementation of the package operates via a menu driven shell that insulates the user from the usual machine and file manipulations typical of

batch program implementation. The HEC-DSS linkage is functional for the flood damage programs EAD, SID, SIDEDT, PIP; basic data management features of HEC-DSS, with editing and help (on-line program user input descriptions) features are provided via use of COED (a Corps developed text editor).

HEC staff participated in development of a technical guide for the computation of agricultural flood damage. The task force developed document, led by the Institute for Water Resources (IWR), has been published and distributed to Corps offices. The HEC developed AGDAM computer program performs a detailed analysis of agricultural flood damage using an event-frequency concept as an alternative to the continuous record method that is presently in common usage. The concepts embodied in the program were incorporated into the technical guide. A near-real time flood damage computation program implementing features of several HEC programs, but on an District-wide event basis is under development.

Spatial Data Management

The HEC has been engaged in activities in the spatial data management area for the past ten years. The HEC-SAM system evolved to provide computational capability in this area. It is comprised of a family of computer programs that are a mix of HEC developed programs, programs adapted from other Corps office programs, and programs acquired in the commercial marketplace (that are proprietary). There are ten programs that comprise the mainframe/minicomputer version of the HEC-SAM. A number of these programs have been adapted to the microcomputer environment. The programs are functional, but somewhat outdated and continue in modest use within the Corps. The need for a fully integrated Corps-developed and -maintained geographic information system (GIS) is open to question. Very good commercial capability is generally available, as are microcomputer workstation based systems. There does continue to be needed the basic capability to independently create, edit, manage, and use spatial data files so as to not become vulnerable to a completely commercial, proprietary system. Smaller-scaled capabilities for use in the PC environment would have day-to-day application to Corps work.

HEC has been working toward a microcomputer GIS system with meaningful progress. A lightweight, portable, microcomputer compatible digitizing tablet has been acquired and successfully used in several HEC projects. A companion microcomputer GIS has been acquired and is undergoing testing. The system was developed by and is available through a public institution. The system looks promising.

Two recent projects demonstrate the types of applications that are occurring in the general planning and evaluation area. A spatial data base was created encompassing the Rio Grande flood plain between Cochiti and Elephant Butte dams and was subsequently used to evaluate the impacts of potential dam-breach floods as part of a dam safety research project. A report will be published documenting the research project. A summary paper is also under preparation that documents and illustrates the application of spatial data management to this study. In another application, the project economic analysis for the Ocean City project was based on spatial analysis. Several years ago a spatial data bank was constructed for the project area and used in performing the flood damage analysis. HEC assisted the Baltimore District in updating the data bank and performing a re-analysis of the economic feasibility of the project.

Water Supply Planning

The HEC is committed to developing study methods and analytical procedures to aid in water supply planning and analysis. Work in this area continues to grow in spite of water supply being considered an incidental interest of the Corps. Work has been accomplished in several important areas: development of a document on conjunctive use planning, substantial progress on a number of policy-oriented studies, training, and workshops.

In cooperation with IWR, the HEC completed an investigation of elements of conjunctive use planning. Several contractors prepared technical material for the work and the HEC consolidated the elements into a coordinated product. A final document will be published in early FY 1988.

Several studies were undertaken to support HQUSACE policy needs. The studies were performed under the IWR Policy Studies Program. One study investigated lessons learned from activities undertaken by the Corps in the Southeast during the recent (1985-86) drought. This effort will be of assistance to Corps offices in other regions in planning for drought. Another study documents opportunities for the Corps to reallocate existing reservoir project storage from present use to water supply needs. A third study looked into an analytical procedure for computing the reservoir cost to be allocated to water supply where the reservoir may have lost utility since its construction from such factors a sedimentation.

Training activity in this area was intensive. A PROSPECT course entitled "Water Supply Hydrology" was presented, and workshops on "Microcomputer Applications in Water Supply Analysis", and "Reservoir Storage Reallocations for Water Supply" were also held. Training

courses to be present in FY 1988 in this area are "Ground-water Hydrology", and "Groundwater Quality". A tutorial was also finalized that documents a case example of applying desk-top analysis methods (non-computer model analysis) appropriate for early stages of groundwater oriented studies. The case example is the Reelfoot Lake, Tennessee investigation.

Miscellaneous

Several years ago, the HEC developed a computer program to assist in planning for dredged-material disposal. The program is known as the Dredged-Material Disposal Management Model (D2M2). Given a potential array of disposal sites and dredged material sources and characteristics, the program selects an optimal ensemble of sites and efficient routing of dredged-material to the appropriate sites. This year, improvements were made to the computer programs by enhancing capabilities, improving computational algorithms, and developing microcomputer branch-and-bound search programs that can be used independently of the comprehensive modeling program.

Two separate projects were undertaken in support of flood plain management activities. A document was prepared that provides guidelines for actions needed by potential developers who wish to develop within the floodway portion of the flood plain. Guidelines are provided on the technical analysis needed to support a development approval request, impact mitigation measures, and documentation requirements. The other project is an extension of the computed water surface profile accuracy research reported in the FY 1986 annual report. The profile accuracy study objective was to develop a strategy to enable obtaining a desired water surface profile accuracy given stream characteristics and available mapping technologies for determining stream geometry. The essential findings of that investigation are being implemented in an interactive microcomputer computer program. The program is scheduled for release in the first quarter of FY 1988.
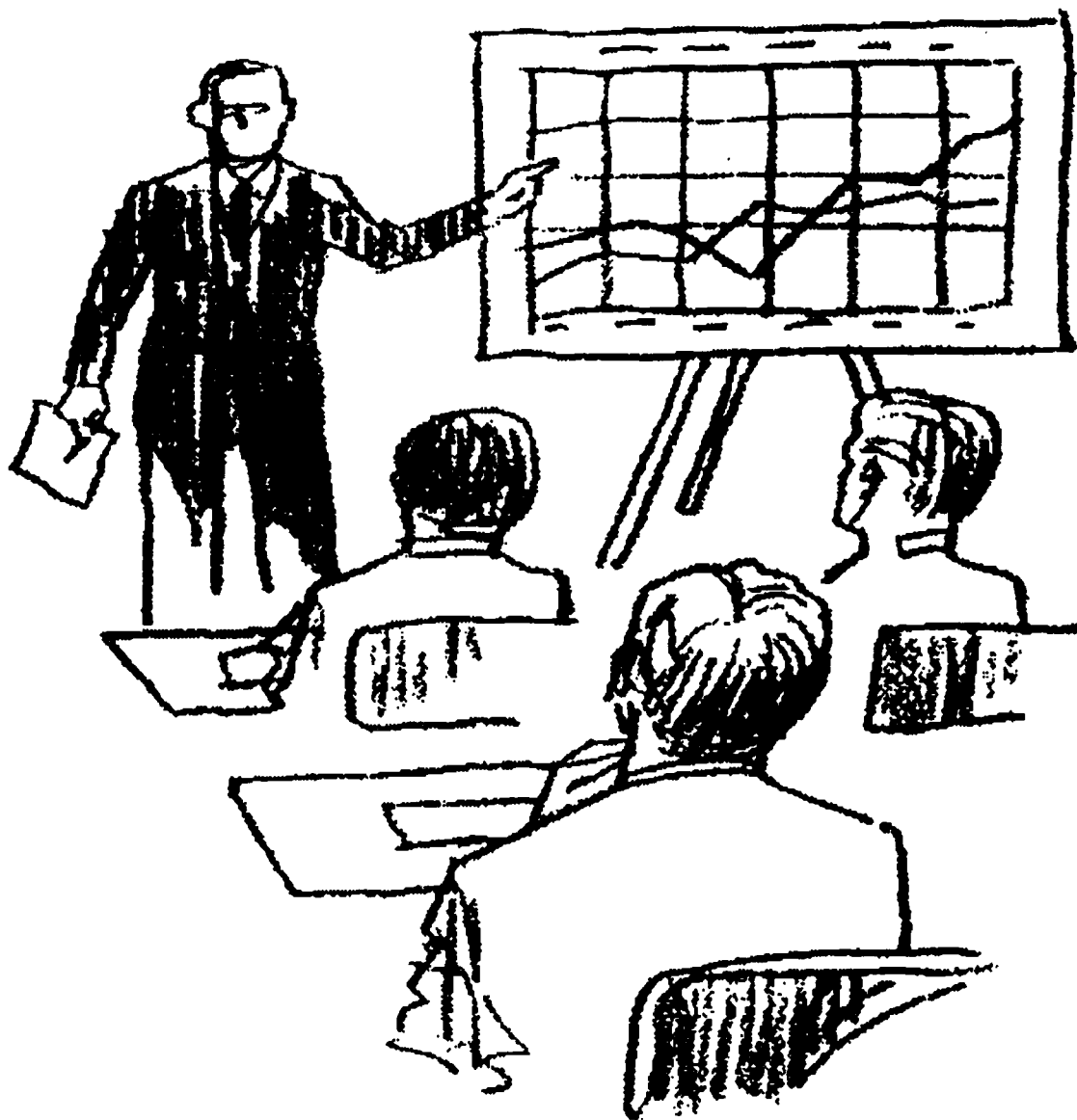
TRAINING

The training activities of the Hydrologic Engineering Center (HEC) are designed to increase the technical capabilities of the Corps field offices to meet needs and solve problems in hydrologic engineering and water resource planning. The training effort is designed to assist field offices in their application of computer technology to the complex problems associated with water resource management. This technology transfer is carried out through a regularly scheduled set of training courses, special workshops designed to meet specific needs, state-of-the-art seminars, training assignments of individuals, and distribution of training course video tapes and a variety of technical publications. The emphasis is on practical applications such as utilizing appropriate technology to solve real-world problems.

Training Courses. About ten courses are conducted each year under the Proponent Sponsored Engineers Corps Training (PROSPECT) Program. Courses are one or two weeks in duration, and include formal lectures and practical problem-solving workshop sessions. Guest instructors from other Corps offices, universities and private industry are invited to participate. These instructors supplement the capabilities of the Center's staff.

Workshops. Special workshops are conducted each year at the request of individual District or Division offices. The requested workshop may be similar in content to one of the regular courses, or it may focus on a particular need for which training is not available elsewhere. The duration of these workshops range from one day to one week. They

are usually held at the requester's office to allow greater participation by the staff of the requesting Corps office, as well as local, state and other federal agencies.

Seminars. Seminars provide a forum for discussion of field problems and current solutions and for identification of needs for new techniques. The papers presented by participants are published as seminar proceedings.

Individual Training. A District or Division may request individualized training for one or more persons on prearranged topics. Also, training arrangements may provide for the individual to work under the direction of HEC personnel on a problem from the home office.

Video Tapes. Over the past eleven years, HEC has made video tapes of selected training course lectures. These tapes (with supporting lecture notes) are loaned on request. The tapes are intended to supplement the training program by providing the course material to those unable to attend courses.

Training Materials. Materials prepared and distributed as part of HEC's training program include training course manuals and training documents which illustrate procedures for solving technical problems or for applying computer programs.

Training Program Accomplishments, FY 1987

The HEC conducted a total of 16.5 weeks of training during FY 1987. Courses and workshops, and seminar conducted were:

Formal Courses (11 weeks - 8 courses)

Basic HEC-2 (20-24 Oct 86)

Reservoir System Analysis (1-12 Dec 86)

Water Resources Data Management
(12-16 Jan 87)

Flood Damage Analysis (2-6 Feb 87)
Hydrologic Analysis of Floods
(2-13 Mar 87)

Hydrologic Engineering for Planning
(6-10 Feb 87)

Unsteady Flow (1-12 Jun 87)

Water Supply Hydrology (24-28 Aug 87)

Workshops (4.9 weeks - 7 workshops)

Flood Forecasting, 4 days,
Vicksburg, MS

Water Control DSS, 3 days,
Detroit, MI

Flood Warning, 1 day, Washington, DC

Water Quality Modeling (with WES),
5 days, Denver, CO

Water Control, 3 days, Cincinnati, OH

Reconnaissance Studies, 2 days,
Davis, CA

Flood Preparedness, 5 days, Davis, CA

Seminars (.6 weeks)

Local Flood Warning and Response
Systems, 3 days, Asilomar, CA

Video Tapes

Starting in FY 1987, all loan tapes were only available in the 1/2 inch VHS format. During FY 1987, 63 new lectures were added to the library bringing the total to 581 lectures.

Training Program for FY 1988

The training program planned for FY 1988 is based on a survey of training needs conducted by the CE Training Management Division in Huntsville and on the recommendations of OCE course proponents on the technology transfer needs required to serve Corps missions. Fifteen HEC training courses were surveyed for Corps-wide participation during FY 1988. Twelve received sufficient enrollment to justify conducting the course, and one, Hydrologic Engineering for Planning, received enough to conduct the class twice.

HEC Training Schedule for FY 1988

Course Title	Weeks	Date
Flood Plain Hydrology	2	19 - 30 Oct 87
Hydrologic Engineering for Planning	1	16 - 20 Nov 87
Real-Time Water Control	2	30 Nov - 11 Dec 87
Interior Flooding Hydrology	1	8 - 12 Feb 88
Statistical Methods in Hydrology	2	7 - 18 Mar 88
Flood Damage Analysis	1	11 - 15 Apr 88
Hydrologic Engineering for Planning	1	25 - 29 Apr 88
Advanced HEC-2	1	9 - 13 May 88
Hydrologic Data Management	1	23 - 27 May 88
Planning for Hydrologic Engineers	1	6 - 10 Jun 88
Sediment Transport	2	11 - 22 Jul 88
Groundwater Hydrology	1	15 - 19 Aug 88
Groundwater Quality	1	22 - 26 Aug 88

COMPUTER PROGRAM SUPPORT

The Computer Program Support program at HEC is designed to provide user assistance and to produce and distribute documentation of newly developed and improved programs to aid users in the solution of hydrologic engineering problems. The HEC focuses a substantial portion of its resources on the development and documentation of "generalized" computer programs. Documentation includes user and programmer manuals for computer programs, training documents, technical papers, research and project reports, and seminar proceedings. During FY 1987 HEC distributed approximately 16,000 publications.

New and revised documentation issued during FY 1987 are listed below. A catalog of HEC publications is available on request.

Computer Program Documentation

HEC-5 Appendix on Water Quality Analysis

HECDSS - Users Manual

COED - Users Manual

HECDSS - Programmers Manual

Technical Papers

No. 112 New Developments in HEC
Programs for Flood Control

No. 113 Modeling and Managing Water
Resource Systems for Water
Quality

No. 114 Accuracy of Computer Water
Surface Profiles... Executive
Summary

No. 115 Application of Spatial Data
Management Techniques in Corps
Planning

No. 116 The Hydrologic Engineering
Center's Activities in Watershed
Modeling

No. 117 HEC-1 and HEC-2 Applications
on the Microcomputer

Research Documents

No. 25 Reservoir Operation During
Drought: Case Studies

No. 26 Accuracy of Computer Water
Surface Profiles

No. 26D Accuracy of Computed Water
Surface Profiles - Supplement

No. 26A Accuracy of Computer Water
Surface Profiles - Appendix

Seminar Proceedings

No. 17 Local Flood Warning - Response
System

Training Documents

No. 26 Computing Water Surface Profiles
with HEC-2 on a Personal
Computer

Current HEC Computer Programs

Source code and test data for the HEC computer programs listed in the following table are available from HEC. These programs are written in FORTRAN and provided on magnetic tape or floppy diskettes. Most of these programs are operational on the HARRIS 500 and 100 systems, and have been distributed to Corps offices. The programs are also available to Corps office via access to the Control Data Cybernet (CDC) system. Many have been modified to FORTRAN 77 standards and many are also available as microcomputer versions.

The HEC has also been delegated authority by the Department of the Army to release hydrologic engineering computer programs to public agencies and private firms. This delegation of authority was granted to minimize delays which occurred in processing requests for programs through the several approval levels normally required by the Corps and Department of the Army. Some of the programs contain proprietary code, use a special data storage system, or are not up to HEC standards and are available only to Corps of Engineers offices. Only those programs with an "availability" of ALL will be released to other public agencies and private firms.

While the Government is not responsible for the results obtained when these programs are used, assistance in resolving any malfunction of the programs is furnished by HEC to the extent that time and funds are available. The list of programs, by technical subject, also indicates the distribution and micro version availability. Brief descriptions and computer hardware/software requirements for the programs are contained in HEC's Computer Program Catalog.

LIST OF COMPUTER PROGRAMS BY TECHNICAL SUBJECT

| Program Name	Program Availability	Micro Version Availability	Program Title
DATA STORAGE SYSTEM (DSS)			
CONVRT	DSS Sites Only		Convert Data to Stage, Including Precipitation
DATMAN	DSS Sites Only		Daily Time Series Data Management Program - DSS
DSPLAY	DSS Sites Only		Display DSS
DSSIN	DSS Sites Only		Time Series Data to DSS
DSSITS	DSS Sites Only		Enter Irregular Time Series in DSS
DSSPD	DSS Sites Only		Enter Paired Data in DSS
DSSSHF	DSS Sites Only		Output DSS Data in SHEF Format
DSSTS	DSS Sites Only		Enter Time Series in DSS
DSSUTL	DSS Sites Only		HECDSS Utility Routines
EXTRCT	DSS Sites Only		Extract Data From DSS File
GOESLD	WC Harris Sites Only		Load GOES Data - DSS
MATHPK	DSS Sites Only		Mathematical & Statistical Analysis of Data Stored in a DSS File
MISFOR	DSS Sites Only		LMVD Forecast Program - DSS
NWSDSS	DSS Sites Only		Load NWS Data Tapes in DSS
PIP	DSS Sites Only		Paired Function Input Program - DSS
PREDWN	DSS Sites Only		DWOPER DSS Preprocessor
REPGEN	DSS Sites Only		Report Generator
SHFDSS	DSS Sites Only		Load SHEF Data in DSS
WATDSS	DSS Sites Only		Load WATSTORE Data in DSS
GROUNDWATER HYDROLOGY			
FEMFLO	All		Finite Element Solution of Steady State Potential Flow Problems
GWMODL	Corps Only	1984	Groundwater Model
GWPOST	Corps Only	1984	Groundwater Model Post Processor (SOL)
GWPREP	Crops Only	1984	Groundwater Model Pre-Processor
GWSP	Corps Only	1984	Groundwater Simulation Package
PLANNING ANALYSIS			
AGDAM	All		Agricultural Flood Damage Analysis
D2M2	All	1986	Dredged-Material Disposal Management Model
DADS	Corps Only		Parameter Generation Program (Kriging)
DAMCAL	All	1986	Damage Reach Stage-Damage Calculation
DEMAND	All	1986	Model for Estimating Water Demands
EAD	All	1984	Expected Annual Flood Damage Computation
HYCOST	All	1984	Small-Scale Hydroelectric Power Cost Estimates
PBA	Corps Only		Project Benefit Analysis (Including PPBA)
PINA	All		(PINA,SIPP) Interactive Nonstructural Analysis Package
SID	All	1985	Structure Inventory for Damage Analysis
SIDEDT	All	1985	Structure Inventory for Damage Analysis Edit

Program Name	Program Availability	Micro Version Availability	Program Title
RESERVOIRS			
CKHEC5	All	1987	Input Data Checking Program for HEC5
DELTAS	All		Reservoir Delta Sedimentation
DEPOSS	All		Deposit of Suspended Sediment
HEC3	All		Reservoir System Analysis for Conservation
HEC5	All	1987	Simulation of Flood Control and Conservation Systems
HYDUR	All		Hydropower Analysis Using Streamflow Duration Procedures
INCARD	All		Flow Conversion for HEC5
INFIVE	All	1985	Interactive Input Preparation Program for HEC5
RESACT	All	1986	Reservoir Area-Capacity Table by Conic Method
RESYLD	All	1986	Reservoir Yield
SWGRC	All		Spillway Gate Regulation Curve
SWRFR	All		Spillway Rating and Flood Routing
SWRPTG	All		Spillway Rating-Partial Tainter Gate Opening
RIVER HYDRAULICS			
CFLDRT	Corps Only		Comparative Analysis of Flood Routing Methods
CHANOP	Corps Only		Channel Structures Operation
CONTUR	Corps Only		Contour Plotting Program for RMA2
DAMBRK	Corps Only		NWS Dam Break Model
DAMPRE	Corps Only		Pre-Processor for NWSDMBRK Program
DWOPER	Corps Only		NWS Unsteady Flow
EDIT2	All	1984	HEC2 Data Editor
GEDA	All		Geometric Elements from Cross Section Coordinates
H2ED95	Harris Sites Only		Program that Edits TAPE95 (generated by HEC2)
HEC2	All	1986	Water Surface Profiles
HEC6	All	1986	Scour and Deposition in Rivers and Reservoirs
HGP	All		Hydraulics Graphics Package
PATH	Corps Only		Pathline Plotting Program for RMA2
RMA-1	All		Finite Element Network Generator
RMA-2	All		2-D Finite Element Hydrodynamics (Horizontal)
RMA-7	Corps Only		2-D Finite Element Hydrodynamics (Vertical)
RMA-8	Corps Only		3-D Finite Element Hydrodynamics
SHP	All		Stream Hydraulics Package
SSYLD	All		Suspended Sediment Yield
SUMPO	All	1985	Interactive Summary Printout Using HEC2
USTFLO	All		Gradually Varied Unsteady Flow Profiles
VECTOR	All		Vector Plotting Program for RMA2
SPATIAL DATA MANAGEMENT			
AUTOMAPII	Corps Only		Line Printer Graphics for Polygon Data
BANK	All	1985	Data Bank Manager
FOURV	All		Perspective Plot
GRDPLT	Corps Only		Pen Plot of Grid Cell Data
GRIPS	Corps Only		Polygon to Grid Conversion
PLYPLT	Corps Only		Pen Plot of Polygon Data
REGIST	All		Data Registration Program
RIA	All	1985	Resource Information and Analysis

21

Program Name	Program Availability	Micro Version Availability	Program Title
STATISTICAL HYDROLOGY			
HEC4	All		Monthly Streamflow Simulation
HECWRC	All	1985	Flood Flow Frequency Analysis
MLRP	All	1986	Multiple Linear Regression Program
PDILFE	All		Partial Duration Independent Low Flow Events
REGFQ	All		Regional Frequency Computation
STATS	All	1985	Statistical Analysis f Time Series Data
SURFACE WATER HYDROLOGY			
BALHYD	All		Balanced Hydrograph
BASINC	All		Basin Rainfall and Snowmelt Computation
FORCST	All		Forecast River Flows by Regression
HEC1	All	1985	Flood Hydrograph Package
HEC1CV	All		HEC1 Input Converter
HEC1F	WC Harris Sites Only		Modified HEC1 for Real-Time Water Control Systems
HMR52	All	1985	Probable Maximum Storm (Eastern U.S.)
HYDCR	All		Hydrograph Combining and Routing
HYDPAR	All	1985	Hydrologic Parameters
INTDRA	All		Interior Drainage Flood Routing
OPROUT	All		Stream Routing Optimization by Negative Local Flows
PRECIP	Corps Only		Basin Precipitation Computations
SFRO	All	1986	Streamflow Routing Optimization Using Local Flow Pattern
STORM	All		Storage, Treatment, Overflow, Runoff Model
UHCOMP	All	1986	Interactive Unit Hydrograph and Hydrograph Computation
UHHC	All		Unit Graph and Hydrograph Computation
UHLRO	All		Unit Graph and Loss Rate Optimization
UTILITIES			
BB	Harris Sites Only		Bulletin Board
COED	All	1985	Corps Editor
FSIR	All		Fortran Source Inventory and Renumbering
HECLIB	Corps Only		HEC Subroutine Library
REPLST	Harris Sites Only		Report Lister
REPUTL	Harris Sites Only		Report Utility Processor
VERFIL	Corps Only		Text File Verification
WATER CONTROL			
APEX	Harris Sites Only		Initiate Clock Schedule Tasks
ASYNC	Harris Sites Only		Asynchronous Communication - Real Time
ASYNCI	Harris Sites Only		Interactive Asynchronous Communication
DATAST	WC Harris Sites Only		Data Status
IDXNWS	WC Harris Sites Only		Index AFOS Products
LODNWS	WC Harris Sites Only		Load AFOS Products
MODCON	WC Harris Sites Only		Interactive Executive for Model Control

Program Name	Program Availability	Micro Version Availability	Program Title
MONNWS	WC Harris Sites Only		Monitor NWS Dedicated Line
PREOP	WC Harris Sites Only		Pre-Operations Data Preparation
SNOSIM	WC Harris Sites Only		Snowmelt Simulation
VUENWS	WC Harris Sites Only		View NWS Products

WATER QUALITY

Program Name	Program Availability	Micro Version Availability	Program Title
HEATX	All		Heat Exchange Program
HEC5Q	All		Simulation of Flood Control and Conservation Systems (Including Water Quality Analysis)
RESTMP	All		Reservoir Temperature Stratification
RMA-4	Corps Only		2-D Finite Element Water Quality
RWQM	All		Receiving Water Quality Model
THERMS	All		Thermal Simulation of Lakes
WEATHR	All		Weather
WQPLOT	All		Water Quality Plot (WQPLOT)
WQPROF	All		Water Quality Profile (WQPROF)
WQRRS	All		Water Quality for River-Reservoir Systems
WQRRSQ	All		Stream Water Quality (WQRRSQ)
WQRRSR	All		Reservoir Water Quality (WQRRSR)
WQSTAT	All		Water Quality Statistics (WQSTAT)
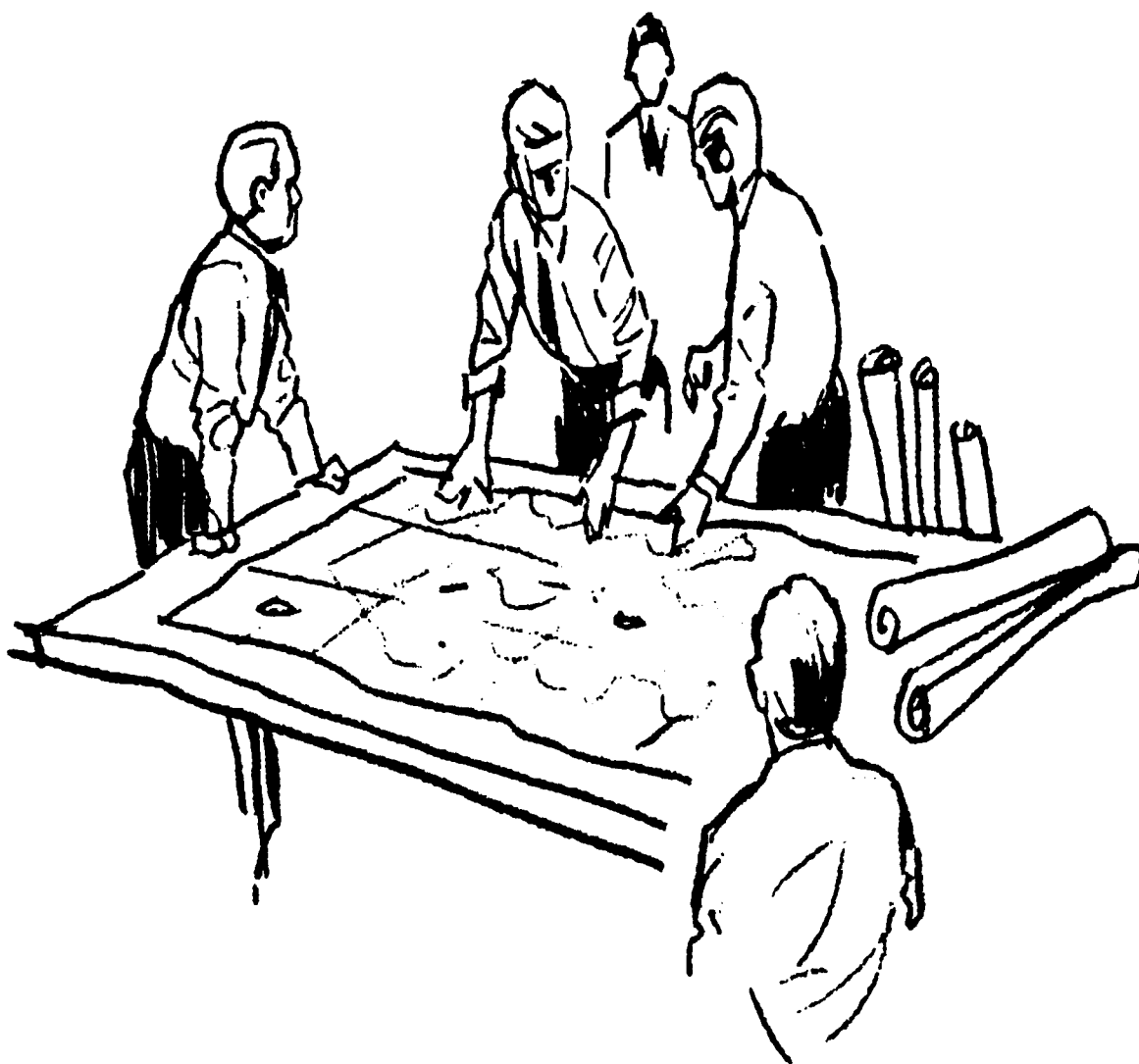
TECHNICAL ASSISTANCE

The primary objective of the technical assistance program is to provide assistance and guidance to requesting Corps field offices in the application of hydrologic engineering and planning techniques to solve water resource problems. Technical assistance activities are conducted jointly on a cooperative and reimbursable basis. These activities enable HEC's technical staff to maintain close contact with Corps personnel in District and Division offices and to evaluate the effectiveness of new technology in a "project application" mode. This collaboration results in more complete and efficient solutions to complex problems, a continual improvement in methods, the testing and appraising of new approaches, and the recognition of needs for new research and training.

Each division of HEC helps Corps offices to apply models and to meet special needs with new developments, and acts in an advisory capacity in a number of technical subjects and A-E contracts depending on technical specialties and work load. Studies range in scope from brief reviews of work done by others to major studies requiring a team effort by several members of the HEC staff.

FY 1987 Accomplishments

A total of $ 1,055,000 in technical assistance effort was expended in FY 1987 supporting 23 offices. The offices included 12 Corps Districts; 4 Corps Divisions; the Office of the Chief of Engineers (OCE); the Water Resources Support Center (WRSC); the Institute for Water Re-

Number	Title	Date
87-1	Monongahela River Basin Water Quality Modeling Study (HEC-5Q)	Feb 87
87-2	Real-Time Flood Forecasting and Reservoir Regulation for the Calaveras River Basin	Apr 87
87-3	Numerical Simulation of the Response of Cache Creek to the Modification of the Clear Lake Outlet	Aug 87

sources (IWR); the Waterways Experiment Station (WES); the Cold Regions Research and Engineering Laboratory (CRREL); the Federal Highway Administration (FHA); and the Federal Emergency Management Administration (FEMA). Major projects are listed in the above table.

In the area of data management, assistance was furnished to the Southwestern Division to provide capabilities to manage text and graphic products received from the National Weather Service AFOS communications circuits and to the St. Louis District to enhance their DATMAN system used to manage daily Mississippi River related data for historical storage and publication.

A major effort was completed in the final editing of the Engineering Manual on Water Control Systems (EM 1110-2-3600). River Hydraulics studies constituted about twelve percent of all technical assistance effort. Work was performed for FEMA to help define the floodway where normal procedures are not appropriate and for FHA to develop an interactive PC program to implement the results of the water surface profile accuracy study.

Rainfall-Runoff modelling was a part of several studies including the Prompton Lake modification analysis for the Philadelphia District, and the remote sensing demonstration project in the Rock Island District where a continuous simulation implementation of HEC-1F is being developed. Reservoir system analysis is a part of the Prompton study as well as the major focus of work being done for the South Atlantic Division in developing a reservoir system model of their area of responsibility. IWR sponsored several components of a study of policy issues involved in reallocation of reservoir storage for water supply.

Of the 4 studies involving sediment transport, the Cache Creek analysis for the Sacramento District was the most significant effort.

The development of regulated flow frequency curves downstream of Corps projects was the focus of a study for the Savannah District. This analysis required the processing of a period of record data as well as data for major flood events. A second study of a statistical nature funded by OCE looked at the impact of the length of the data record and the particular analysis period to access the reliability of the frequency curve and the stability in computed project benefits.

A major assistance and development effort in water control activities was funded by the Sacramento District. This work provided for the development of new data entry software, enhancements to the graphical display routines and the modeling of an example Sierra-Nevada basin. Assistance was provided to the Pittsburgh District in modeling the Allegheny River basin. Water Control field support to Corps Districts was funded by OCE.

Water Quality support to Corps field offices was funded through the Waterways Experiment Station under the Water Operations Technical Support (WOTS) program. Water supply studies were funded by IWR in the areas of Conjunctive Use, and Water Supply Policy Issues.

Other studies not included in the above categories included workshops for the Lower Mississippi Valley Division, the Detroit District, and OCE, and assistance to the Philadelphia District in navigation planning. The workshops covered material on flood forecasting, the Data Storage System, and flood warning and response systems, respectively.

Technical Assistance Projects
FY 1987 - Expenditures*

Data Management (Total of 3 projects; $48,000)
SWD - AFOS Products Storage/Retrieval/Display
LMS - DATMAN Data System Enhancements

Engineering Guidance (Total of 3 projects; $19,000)
OCE - EM 1110-2-3600 Water Control Systems

Economic/Planning Analysis (Total of 5 projects; $12,000)

River Hydraulics (Total of 6 projects; $127,000)
OCE - Flood Plain Management User Support
FEMA - Floodway Evaluation
FHA - Profile Accuracy Program

Rainfall-Runoff Analysis (Total of 5 projects; $114,000)
LMS - H & H Model Studies
NAP - Prompton Model Study
CREEL - Remote Sensing Forecast Demonstration

Reservoir System Analysis (Total of 7 projects; $ 98,000)
OCE - Reservoir Regulation Development Support
SAD - System HEC-5 Model Development
IWR - Reservoir Storage Reallocation Study

Sediment Analysis (Total of 4 projects; $48,000)
SPK - Cache Creek HEC-6 Study

Statistical Analysis (Total of 2 projects; $ 45,000)
OCE - Stochastic Simulation Study
SAS - Flood Frequency Curves

Water Control (Total of 5 projects; $295,000)
OCE - Water Control Maintenance Support
LMV - Real Time Software Development
LMS - Recurring Report Forms
SPK - W. C. System Implementation
ORP - Allegheny River Model Development

Water Quality (Total of 2 projects; $31,000)
WES - WOTS Field Support

Water Supply (Total of 5 projects; $72,000)
IWR - Water Supply Planning
IWR - Conjunctive Use Planning
IWR - 1986 Drought

Other (Total of 12 projects; $146,000)
OCE - Flood Warning Workshop
OCE - Modify HASP RJE Emulator
NAP - Navigation Planning Assistance
LMV - Flood Forecasting Workshop
NCE - Data Storage System Workshop
IWR - Training Support

* Only major projects shown ($10,000 or more)

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